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RESEARCH NOTES:

March 2002

SINGLE POINT URBAN INTERCHANGES WITH FRONTAGE ROADS

One of the most important elements of our transportation infrastructure is the urban diamond interchange. There are several reasons for this, some of which are as follows:

- Operations. Historically, interchanges, especially diamond interchanges, have been among our most congested facilities. Reasons for this may include rapid increase in traffic volumes, under-projected design volumes, imprecise analysis tools and less than optimum operational methods.
- Right-of-way and construction costs. Because of high right-of-way costs in urban areas, extra roadway capacity may not have been provided where it is otherwise desirable.
- Safety. With the high volumes of arterial street traffic interfacing with the large turning movements to and from a freeway, the diamond interchange is one with significant potential for traffic crashes.

In recent years, Arizona has seen considerable use of the single-point urban interchange (SPUI), which has become very popular with roadway designers and the motoring public. Some reasons for its popularity include:

- Increased left turn efficiency potential. The use of "inside left turns" to reduce the number of traffic signal phases for the traditional SPUI increases the left turn efficiency.
- Possibility of reduced arterial street right-of-way. This is primarily because of the use of "inside left turns" from the arterial street can be provided in the same right-of-way longitudinally. This is because they don't overlap across the structure.
- Simplified timing. Conventional diamond interchanges require special signal timing, the phasing for which varies depending on traffic volumes and ramp spacing. The SPUI can be effectively timed using a standard eight-phase signal controller. The only significant difference between timing it and a regular eight-phase intersection is the required change intervals.

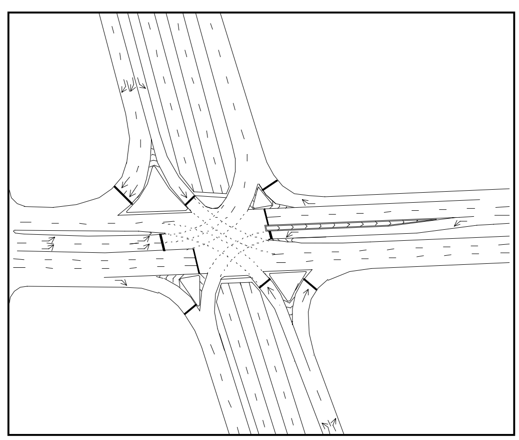

Figure 1. Example of SPUI

There are also disadvantages associated with the SPUI, primarily the increased structure cost due to the large span and the lack of space for a center overpass bridge pier. Additionally, the ramp horizontal geometry necessary to accommodate the inside left turns will often require more right-or-way than the compact diamond.

At first these SPUIs were, almost without exception, constructed on freeways without frontage roads. Because of the reduced right-of-way required on the cross street, the Arizona Department of Transportation (ADOT) has constructed several single-point urban interchanges with frontage roads (SPUI/F). Because of their infrequent previous use there was no data on the safety and operations of these interchanges.

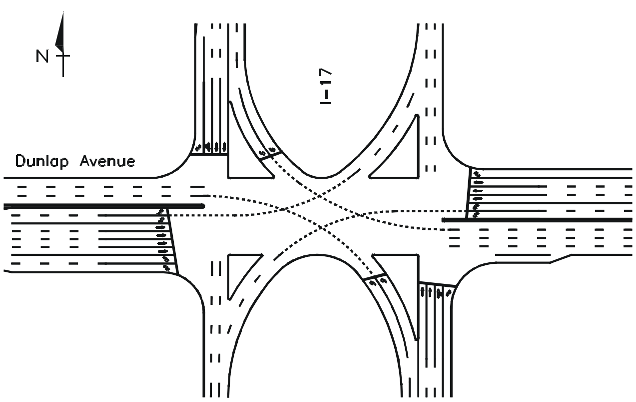

Figure 2. Example of SPUI/F

Approach

This research compared the SPUI/F with the tight urban diamond interchange (TUDI) in the following manner:

1. Evaluate the SPUI/F based on available accident data and conflict analysis techniques, right-of-way and construction costs, and operating efficiency.
2. Compare the performance of the SPUI/F and the TUDI.
3. Evaluate current SPUI/F design assumptions and operation; recommend design and/or operational changes to enhance performance.
4. Evaluate the interchange form selection (pre-design) process; recommend changes where appropriate.

Crash Analysis

A crash analysis was prepared for the portion of the most resent three years of operation at each of the 5 TUDI and 5 SPUI/F where the interchange geometry and operations had not changed. There was no significant difference in the crash rates at the SPUI/F as compared to those at the TUDI. There was a significant difference in the location of those crashes. The greater proportion of rear-end crashes occurred on the frontage roads at SPUI/F. The greater proportion of rear-end crashes occurred on the arterial roadway at TUDI.

Conflict Analysis

At the 0.05 significance level, there was no significant difference between the SPUI/F and TUDI conflict rates., but at the 0.10 significance level, SPUI/Fs had a greater conflict rate than TUDIs.

Some correlation was found between the crash rates and conflict rates of each interchange.

Operations

The sum-of-critical-flow-ratios is a unique parameter that can combine an infinite number of interchange volume level, volume pattern, and geometry combinations into a single value. Furthermore, the analysis indicates that this parameter has a unique delay relationship based on interchange type and phase sequence. These attributes can be exploited to develop a family of characteristic curves for a range of ramp separation distances that collectively can be used to identify the most efficient interchange alternative. An example of this family of curves is shown in Figure 3.

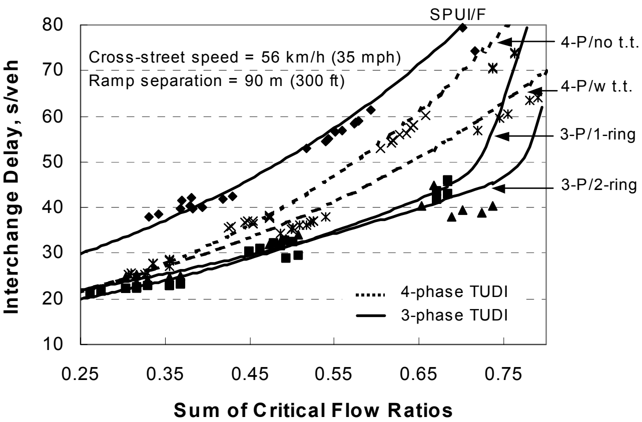

Figure 3. Example of Family of Curves

Cost

A cost evaluation of interchanges can be made in various manners. If one evaluates only right-of-way and construction costs, an alternative may be selected which will provide the least initial cost, however which may result in a higher life cycle cost. This is especially true if one considers the cost to the motoring public. Planning level cost estimates of two interchange types were compared with the actual cost when they were finally built. Although the sample sizes do not permit definitive conclusions, the cost estimates for the SPUI/F appear to have been underestimated.

When one considers the road user costs, the life cycle cost of the TUDI for all three interchanges studied is considerably less than that of the SPUI/F. The primary reason for this is the additional delay at the SPUI/F for interchanges with these ramp separation distances.

Selection Guidelines

The current ADOT process for selecting an interchange type is to generally select the least costly alternative from among those that provide an acceptable operational level. The process was evaluated as it relates to TUDI and SPUI/F and considering the resulting life cycle costs of each type. The operations analysis concluded that operational performance of a SPUI/F degrades rapidly as the distance between the frontage roads increases. This is partially due to the clearance time required as shown in Figure 4. The SPUI/F should only be considered when the spacing between frontage roads is less than approximately 60 m (200 ft). Even then it should only be used when the cost of right-of- way to provide the extra width on the cross street required for the TUDI dual left turns is very expensive. In most cases the TUDI will perform at a level with reduced delay when compared to the SPUI/F, such that life cycle costs analysis will favor the TUDI.

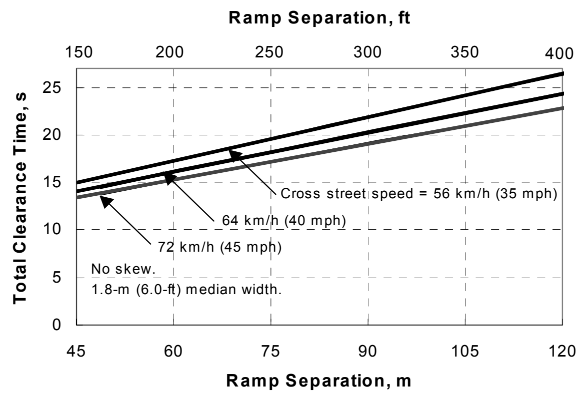

Figure 4. SPUI/F Change Interval

In those situations where right-of-way limitations or cost require consideration of SPUI/F, the selection process can be done in two ways:

1. Comparable Performance Method. This method requires modifying the design of the SPUI/F to not only provide an "acceptable" level of service, but also one that is comparable to that of the competing TUDI design. This would be done primarily by reducing the spacing between the frontage roads, but could also involve the number of lanes. Once a comparable operation between the TUDI and the SPUI/F is achieved, the traditional cost comparison of construction and right-of-way costs can be used to make the selection.
2. Life Cycle Cost Method. This method estimates the present worth of each of the

components of the interchange (e.g. right of way, construction, user costs, etc.). The cost of those components that are not believed to differ between the two types (e.g. crash costs, utilities, etc.) can be ignored in this analysis.

Although there are issues relating to the application of life cycle costs on transportation projects, this research documents the importance of considering future costs, including road user cost, in making decisions on interchange type.

Findings

The findings from the interchange evaluation indicate that a sound, rational approach to interchange form selection and operational evaluation is feasible using the characteristic relationship between interchange delay and the sum-of-critical-flow-ratios. The use of these curves can provide a solution to the challenging question of, "Which interchange form is most efficient?" Previous research projects directed at answering this question have produced guideline statements that can be characterized as vague, subjectively based, or difficult to apply.

The characteristic curves could be used for planning-level and operations-level evaluations. At the planning level, it would be sufficient to identify and sum the critical movement lane volumes and then divide this total by a representative saturation flow rate to obtain the sum-of-critical-flow-ratios. At the operations level, the critical movement flow ratios would be computed and summed. This latter application would incorporate more detail regarding the saturation flow rate of the individual movements.

The only limitation of this approach is that it assumes that a single, actuated controller is used to control the interchange phase sequence. The use of two controllers (i.e., one for each frontage road junction) or the use of pretimed phases would violate key assumptions related to phase time allocation. Such deviations may blur the relationship between the sum-of-critical-flow-ratios and delay.

The presence of high-volume driveways within the TUDI and SPUI/F study area tended to increase the number of conflicts that occurred at an interchange. Driveways should be moved as far from the interchange area as practical.

A common scenario for conflicts on SPUI/Fs occurred between right turns from the cross road, making a right turn on red, and opposing left turns from the cross road.

Interchanges in urban areas must accommodate pedestrians with call buttons and pedestrian signal heads at all crossing locations. The SPUI/F presents some unique pedestrian signalization challenges because of its large size and multiple crossing points These challenges are particularly significant for the pedestrian traveling along the cross street.

The nature of the pedestrian crossings of the frontage road at the SPUI/F appears to result in decreased pedestrian compliance with the pedestrian signals. The signal timing in use required four cycles for the compliant pedestrian to cross the interchange area walking parallel to the cross road. A modified pedestrian timing plan was developed which permits the compliant pedestrian to cross in two cycles. The modified control plan recognizes that the first (and last) pair of roadways encountered can be crossed during one through signal phase. To encourage the pedestrian to complete this crossing, the WALK indication must be of sufficient length to allow the pedestrian to cross the first roadway and the intermediate island. The second roadway is then crossed during the flashing DON'T WALK interval.

The difference in right-of-way costs between SPUI/F and TUDI, which primarily drove the SPUI/F selection becomes relatively insignificant when evaluated on a life cycle cost basis considering road user costs. More emphasis should be placed on efficient traffic operations rather than least initial cost in the selection process.

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